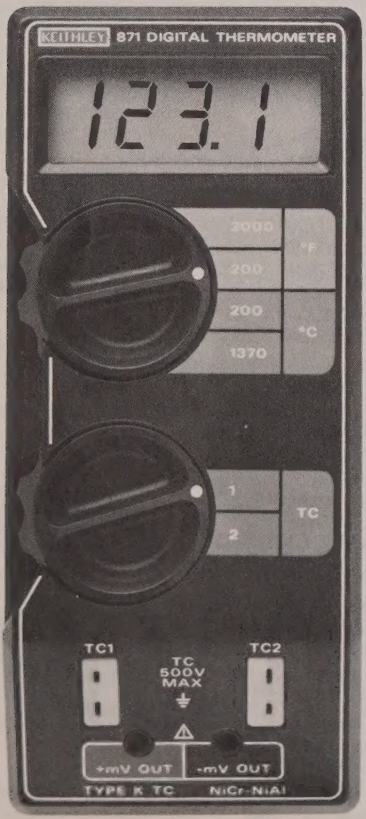
KEITHLEY

# Model 871
# Digital Thermometer
## Instruction Manual



# SPECIFICATIONS

RANGES

**TEMPERATURE SENSOR:** Type K (NiCR-NiAL) thermocouple.

**THERMOCOUPLE INPUTS:** Two, switch selected.

| Ranges | Temperature Span | Resoultion |
|---|---|---|
| 200°F | −40.0 to 199.9°F | 0.1°F |
| 2000°F | −40 to 1999°F | 1°F |
| 200°C | −40.0 to 199.9°C | 0.1°C |
| 1370°C | −40 to 1370°C | 1°C |

**ACCURACY[1]:** ±0.25% of reading ±1°C (0,25% ± 1.8°F)

**REPEATABILITY:** ±0.2°C typical (1 hour, constant ambient temperature).

**TEMPERATURE COEFFICIENT:** 0°-18°C & 28°-50°C): Less than (0.1 × accuracy specification)/°C.

**INPUT CURRENT:** 200nA maximum.

**MAXIMUM ALLOWABLE INPUT:** 150V continuous, 300V momentary (10 seconds).

**NORMAL MODE REJECTION RATIO:** Greater than 45dB at 50 & 60Hz.

**COMMON MODE REJECTION RATIO (1k Ω unbalance):** Greater than 120dB at DC, 50 & 60Hz.

GENERAL

**DISPLAY:** 3½-digit LCD, 0.6" height. Polarity and decimal point indication.

**CONVERSION PERIOD:** 400ms.

**OVERRANGE & OPEN-THERMOCOUPLE INDICATION:** Display blanks except for overrange digit.

**MAXIMUM COMMON MODE VOLTAGE[2]:** Selected TC to mV output; 42V peak. Nonselected TC to mV output; 500V peak.

**mV OUTPUT:** Non-linearized, cold-junction compensated thermocouple output.

**mV OUTPUT ACCURACY (18°-28°C):** ±40μV (°C ranges); ±80μV (°F ranges). Output Resistance=17kΩ. 0°C=0.0mV.

**mV OUTPUT TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C):** Less than (0.1 ×accuracy specification)/°C.

**mV OUTPUT PROTECTION:** 35V maximum.

**ENVIRONMENTAL LIMITS[3]:** Operating: 0°-50°C, less than 80% relative humidity up to 35°C, less than 70% relative humidity form 35°-50°C. Storage:-35°C to 60°C.

**COLD-JUNCTION COMPENSATION:** Semiconductor temperature sensor.

**THERMOCOUPLE LINEARIZATION:** Multi-slope A/D with 11 piece-wise-linear segments between -40°C and 1370°C.

**INPUT CONNECTIONS:** Two, miniature TC connectors.

**mV OUTPUT CONNECTION:** Dual banana jacks.

**POWER:** 9V alkaline or carbon-zinc (NEDA 1604) battery.

**BATTERY LIFE, CONTINUOUS:** 100 hours typical with alkaline battery; 50 hours typical with carbon-zinc battery.

**BATTERY INDICATOR:** Display indicates "BAT" when less than 10% of life remains.

**DIMENSIONS, WEIGHT:** 178mm long×78mm wide×38mm thick (7.0"×3.1"×1.5"). Net weight 300gm (10.6oz).

**ACCESSORIES SUPPLIED:** Battery, manual, Model 8712 Thermocouple Sensor.

[1]1 year, 18°-28°C ambient. Includes repeatability error NBS conformity and cold-junction compensation. Excludes external thermocouple errors. Extended span accuracy -40°C to -55°C: +2°C to 0°C.

[2]WARNING: A shock hazard exists when probes or sensors are exposed to voltage levels greater than 30V rms or 42.4V peak (A.N.S.I.).

[3]Units stored between 0°C and 50°C can be operated for short periods below 0°C.

## Safety Symbols and Terms

The symbol ⚠ on the instrument denotes that the user should refer to the operating instructions.

The **WARNING** used in this manual explains dangers that could result in personal injury or death.

The **CAUTION** used in this manual explains hazards that could damage the instrument.

TABLE OF CONTENTS


| Title | Page | Title | Page |
|---|---|---|---|
| Initial Prepration | 1 | Schematic | 6 |
| Battery Installation/Replacement | 1 | Parts List | 8 |
| Operation Instructions | 2 | Component Layout | 9 |
| Servicing Information | 3 | Troubleshooting Guide | 10 |
| Verification Procedure | 3 | Accessories | 11 |
| Calibration | 3 | Probes and Sensors | 11 |
| Disassembly Instructions | 5 | | |


# INITIAL PREPARATION

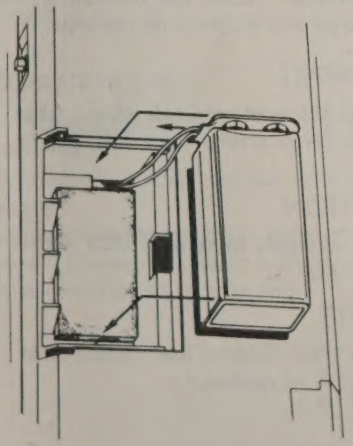
The Model 871 is supplied ready for use with a battery and a thermocouple probe (Model 8712). The thermometer is designed to work with any type-K thermocouple probe or sensor that is terminated with a miniature thermocouple plug. Descriptions of other available probes and accessories can be found in the Accessories Section of this manual.

## WARNING

**Turn the Model 871 off and disconnect the input probes before replacing the battery. Put the cover back into place on the battery compartment before resuming use of the instrument.**

# BATTERY INSTALLATION/REPLACEMENT

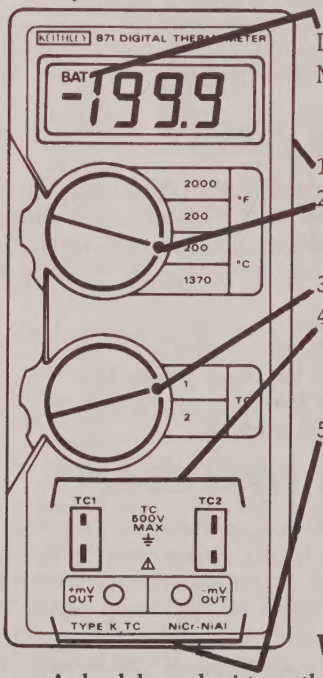
A 9V battery is supplied with the instrument but not installed. To install or replace the battery, remove the cover from the battery compartment by sliding it off in the direction of the arrow located on the battery cover. The battery connector snaps on and off the terminals of the battery. Improper installation of the battery will cause the connecting wires to be severed by excess strain. Proper installation requires that the battery be positioned in such a manner (see drawing) that the leads protruding from the boot of the battery connector face toward the outside of the battery compartment. If the instrument is going to be stored for a long period of time or in a high temperature environment, remove the battery to prevent leakage damage.



7 76 C101

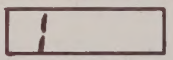
# OPERATING INSTRUCTIONS

The Model 871 Digital Thermometer requires the use of K-type TC probes/sensors, such as the Model 8712 Thermocouple Sensor which is a supplied accessory.




Low Battery Indicator

Minus sign displayed; plus sign implied.



Overranged condition or open thermocouple.

1. SET POWER ON.
2. SELECT SCALE AND RANGE.
   Fahrenheit: 200°F or 2000°F
   Celsius: 200°C or 1370°C
3. SELECT THERMOCOUPLE-TC1 or TC2.
4. INPUT CONNECTORS TC1 and TC2.
   The Model 871 will accommodate one or two probes/sensors that are terminated with standard miniature type K TC plugs
5. ANALOG OUTPUT JACKS.
   +mV OUT and −mV OUT—Use a recorder to monitor temperatures or a sensitive DMM to make high resolution readings. Utilize the NBS Thermocouple Calibration Tables for converting voltage readings into temperature readings.

## WARNING

**A shock hazard exists on the Model 871 input terminals when probes or sensors are exposed to voltage levels greater than 30V rms or 42.4V peak (A.N.S.I.).**

## CAUTION

**To avoid instrument damage do not apply more than 150V across the input terminals of the Model 871.**

## NOTE

Analog output source resistance is 17kΩ. External load resistance of ≥ 10MΩ keeps loading error ≤0.17% of reading.

# SERVICING INFORMATION

## Verification Procedure

### FUNCTIONALITY CHECK:

While holding the tip of a clean TC probe between your thumb and index finger, a reading ascending to between 25° and 40°C should be realized to confirm the functionality of the Model 871.

### ACCURACY CHECK:

1. Prepare a pure-water ice bath as explained in the Calibration procedure (Setup, step 6).
2. Connect a TC probe to Input Channel 1 (TC1) of the Model 871.
3. Immerse the TC probe into the pure-water ice bath and allow 10 minutes for thermal stabilization.
4. Turn on the Model 871 and use the following table to verify that the readings on each range are within specifications.

| Range | Allowable Reading |
|---|---|
| 2000°F | 32° ±2° |
| 200°F | 32.0° ± 1.8° |
| 1370°C | 0° ± 1° |
| 200°C | 0.0° ± 1.0° |

## Calibration

### EQUIPMENT NEEDED:

1. DC Voltage Calibrator with ±0.01% of setting ±20μV accuracy (Fluke 341A or equivalent).
2. 100:1 divider—1.98kΩ and 20Ω resistors, .02% ratio accuracy or better, Wire-wound.
3. Pure-water ice bath—Dewer Flask or 1 quart thermos.
4. K-type TC wire terminated with a standard miniature type K TC plug (see Figure 1) and a copper wire pair.

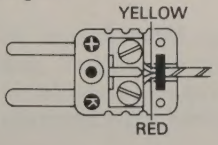



**Figure 1**

## ENVIRONMENTAL CONDITIONS:

Ambient temperature of 23° ±1°C; relative humidity less than 80%.

## SETUP:

1. Turn on voltage calibrator.
2. Connect the TC plug (Figure 1) to the TC1 input of the Model 871.
3. Splice copper wires to the TC wires. Crimp lugs can be used for making the splice.
4. Connect the other ends of the copper wires to the 100:1 divider as shown in Figure 2. Connect the copper/chromel wire to the positive side.
5. Connect the 100:1 divider to the DC voltage calibrator as shown.
6. Prepare the pure water ice bath as follows:
   a. Drill a hole in the cap of a Dewar flask or thermos to accomodate the thermocouples.
   b. Firmly pack the flask with pea-size ice cubes made from distilled water, and then fill the flask with distilled water.
   c. Replace the melted ice with more ice while removing the excess water.
   d. Place the cap on the flask. Immerse the thermocouples into the flask and allow 20 minutes for temperature stabilization.

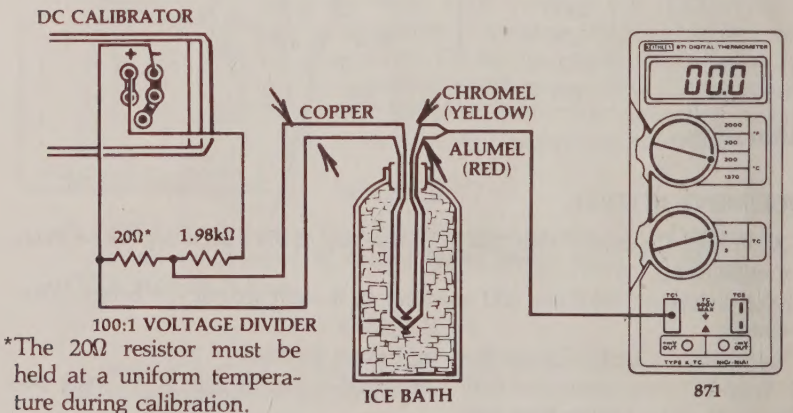
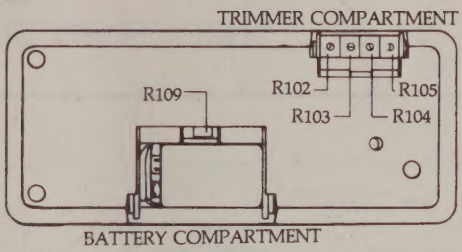



Figure 2

## CALIBRATION PROCEDURE




1. Remove the battery cover and trimmer compartment cover from the Model 871.
2. Turn the Model 871 on and perform the calibration adjustments listed in the following table.

## CALIBRATION ADJUSTMENTS

| Step | Adjustment | 871 Range | Calibrator Setting (V) | Trimmer Adjust | Desired Reading |
|---|---|---|---|---|---|
| 1 | Input Offset Null | 200°C | 0.0000 | R109 | 00.0°C |
| 2 | +Gain(X1) | 1370°C | 5.3093 | R104 | 1320°C |
| 3 | +Gain (X10) | 200°C | 0.6939 | R105 | 170.0°C |
| 4 | -Gain | 200°C | -0.1527 | R103 | -40.0°C |
| 5 | °F Offset | 200°F | 0.0000 | R102 | 32.0°F |

## PROBE MATCHING

To improve the accuracy of the Model 871 while using a particular probe, the calibration of the Model 871 can be adjusted so that probe errors in the region of zero (0°C) are compensated. Place the probe in an ice bath and allow the reading to stabilize. Then reset the zero adjustment (R109) to a 0.0°C reading.

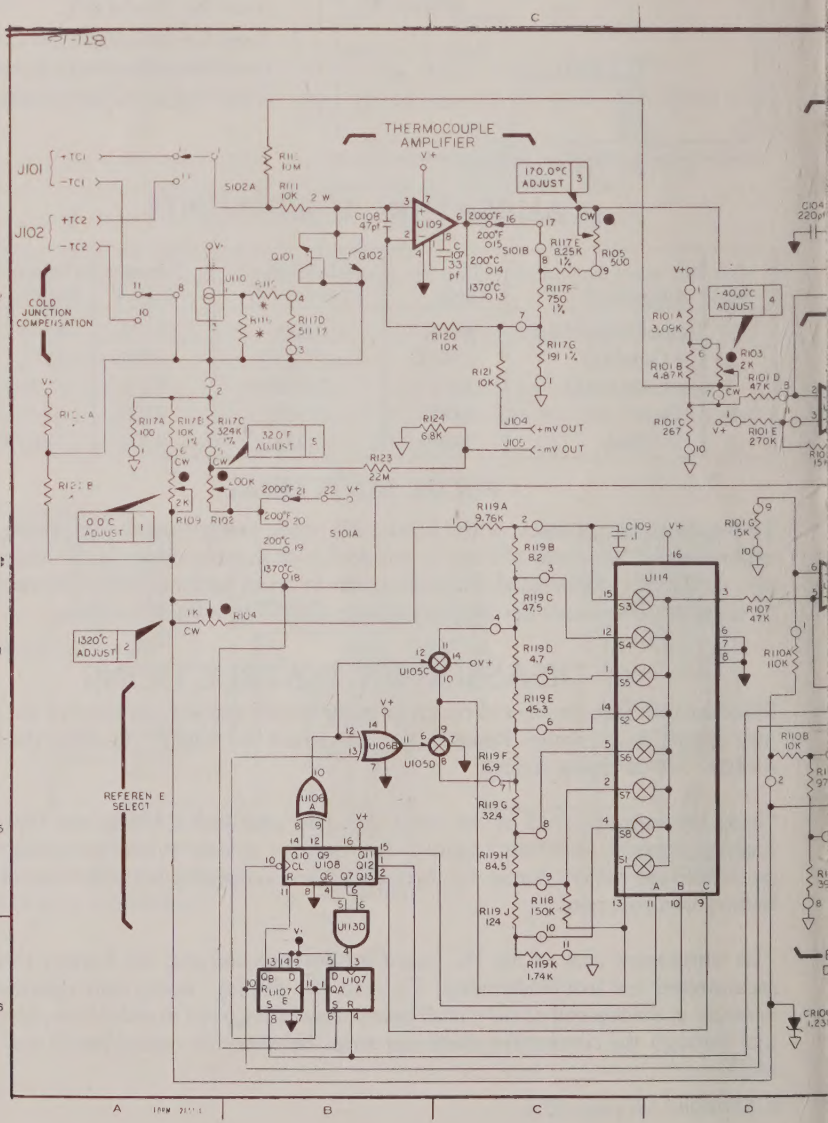
# DISASSEMBLY INSTRUCTIONS

Place the unit face down on a bench or other similar surface and remove the battery compartment cover. Remove and disconnect the battery. Remove the two #4-40× 7/8 retaining screws.

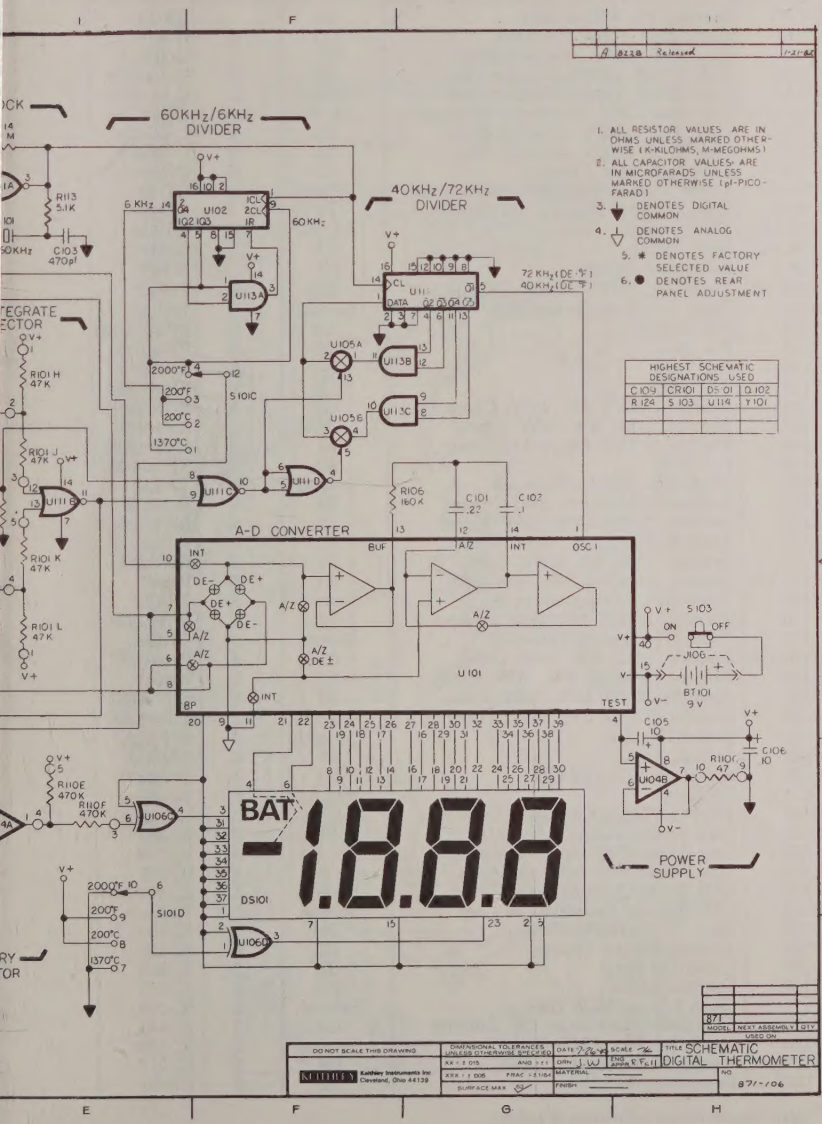
Grasp the bottom cover at the input jack end and with a lifting and forward pushing motion, carefully remove the bottom cover. While removing the cover,feed the battery connector through the access opening in the bottom of the battery compartment.

The component side of the PC board is now exposed and the battery can be reconnected for troubleshooting. To read the display, some light downward pressure at the top end of the circuit board may be required in order to make contact through the conductive elastomer strip, between the circuit board and the LCD.

(Continued on page 10.)


THERMOCOUPLE AMPLIFIER
J101
+TC1
-TC1
J102
+TC2
-TC2
COLD JUNCTION COMPENSATION
S102A
R110 10M
R111 10K 2 W
C108 47pf
U109
170.0°C ADJUST 3
2000°F 16
200°F 15
S101B
200°C 14
1370°C 13
R117E 8.25K 1%
R105 500
C104 220pf
Q101
Q102
U110
R117F 750 1%
R120 10K
R117G 191 1%
R121 10K
R101 A 3.09K
-40.0°C ADJUST 4
R103 2K
R101 B 4.87K
R101 D 47K
R101 C 267
R101 E 270K
R124 6.8K
J104 +mV OUT
J105 -mV OUT
R123 22M
R117A 100
R117B 10K 1%
R117C 324K 1%
320°F ADJUST 5
R122 A
R122 B
0.0°C ADJUST 1
R109 2K
R102 100K
2000°F 21
200°C 20
1370°C 18
S101A
R119A 9.76K
R119B 8.2
R119C 47.5
R119D 4.7
R119E 45.3
R119F 16.9
R119G 32.4
R119H 84.5
R119J 124
R118 150K
R119K 1.74K
C109 .1
U114
R107 47K
R110A 110K
R110B 10K
R101 G 15K
1320°C ADJUST 2
R104 1K
U105C
U105D
U106B
U106A
REFERENCE SELECT
U108
U113D
U107 A
U107 B
R110 7
R110 8
R110 9
R110 10
A
B
C
D

# ATIC
# THERMOMETER

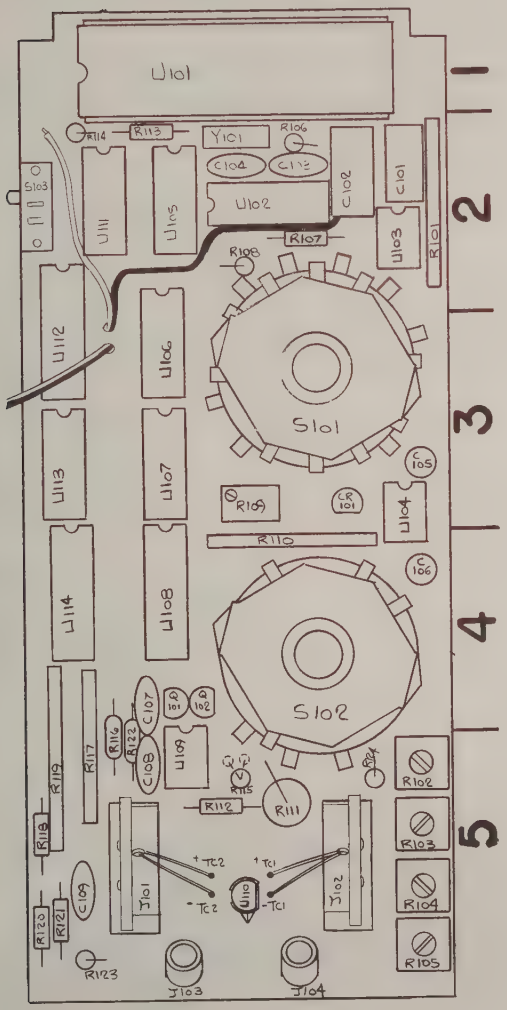


# Parts List

| Circuit Desig. | Description | Schematic Location | PC-Board Location | Keithley Part No. |
|---|---|---|---|---|
| BT101 | Battery, 9V, NEDA 1604 | H4 | | BA-14 |
| C101 | Cap, .22μF, 100V, Polyester | G3 | 2 | C-305-.22 |
| C102 | Cap, .1μF, 160V, Polypropylene | G3 | 2 | C-306-.1 |
| C103 | Cap, 470pF, 1000V, Ceramic Disc | E2 | 2 | C-64-470p |
| C104 | Cap, 220pF, 1000V, Ceramic Disc | D2 | 2 | C-64-220p |
| C105,106 | Cap, 10μF, 16V, Aluminum Electrolytic | H4, H5 | 3, 4 | C-321-10 |
| C107 | Cap, 33pF, 1000V, Ceramic Disc | C2 | 4 | C-64-33p |
| C108 | Cap, 47pF, 1000V, Ceramic Disc | B2 | 5 | C-64-47p |
| C109 | Cap, .1μF, 16V, Ceramic | C3 | 5 | C-238-.1 |
| CR101 | Diode, Low Voltage Reference | D6 | 3 | DZ-62 |
| DS101 | Liquid Crystal Display, 3½ digit | F5 | | DD-27 |
| J101,102 | TC Connector, Female | A1, A2 | 5 | CS-438 |
| J104,105 | Jack, Female | C3 | 5 | 30300-3 |
| J106 | Connector, Battery | H4 | | BH-29 |
| Q101,102 | Transistor, NPN, Switch, 2N3904 | B2 | 4 | TG-47 |
| R101 | Thick Film Resistor Network | Several | 2 | TF-120 |
| R102 | Pot, 200kΩ | A3 | 5 | RP-97-200K |
| R103 | Pot, 2kΩ | D2 | 5 | RP-97-2K |
| R104 | Pot, 1kΩ | B4 | 5 | RP-97-1K |
| R105 | Pot, 500Ω | C2 | 5 | RP-97-500 |
| R106 | Resistor, 180kΩ, 5%, ¼W, Comp | G3 | 2 | R-76-180K |
| R107 | Resistor, 47kΩ, 5%, ¼W, Comp | D4 | 2 | R-76-47K |
| R108 | Resistor, 470kΩ, 5%, ¼W, Comp | E3 | 2 | R-76-470K |
| R109 | Pot, 2kΩ | A3 | 3 | RP-104-2K |
| R110 | Thick Film Resistor Network | Several | 4 | TF-132 |
| R111 | Resistor, 10kΩ, 10%, 2W, Comp | B1 | 5 | R-3-10K |
| R112 | Resistor, 22MΩ, 10%, ¼W, Comp | B1 | 5 | R-76-10M |
| R113 | Resistor, 5.1kΩ, 5%, ¼W, Comp | E1 | 2 | R-76-5.1K |
| R114 | Resistor, 1MΩ, 5%, ¼W, Comp | E1 | 2 | R-76-1M |
| R115,116 | Resistor, Selected, 1%, ⅛W, Mtf. | B2 | 5 | R-88-* |
| R117 | Thick Film Resistor Network | Several | 5 | TF-122 |
| R118 | Resistor, 150kΩ, 5%, ¼W, Comp | C5 | 5 | R-76-150K |
| R119 | Thick Film Resistor Network | Several | 5 | TF-121 |
| R120,121 | Resistor, 10kΩ, 5%, ¼W, Comp | C2 | 5 | R-76-10K |
| R122 | Resistor, Selected, 5%, ¼W, Comp | A3 | 5 | R-76-* |
| R123 | Resistor, 22MΩ, 10%, ¼W, Comp | B3 | 5 | R-76-22M |
| R124 | Resistor, 6.8KΩ, 5%, ¼W, Comp | B3 | 5 | R-76-6.8K |
| S101 | Switch, Rotary | Several | 3 | SW-428 |
| S102 | Switch, Rotary | B1 | 4 | SW-438 |
| S103 | Switch, SPDT, ON-OFF | H4 | 2 | SW-417 |
| TC-1,2 | TC Cable | A1, A2 | 5 | SC-87 |
| U101 | 3½ Digit Single Chip A/D Converter | G4 | 2 | LSI-22 |
| U102 | Dual Synchronous Up Counter | F1 | 2 | IC-282 |
| U103 | Low Power JFET Input Op Amp | D3, D4 | 2 | IC-279 |
| U104 | Low Power JFET Input Op Amp | E5, H5 | 3 | IC-279 |
| U105 | COS/MOS Quad Bilateral Switch | Several | 2 | IC-149 |
| U106 | CMOS Quad Exclusive OR Gate | Several | 3 | IC-226 |
| U107 | Dual "D" Type Flip-Flop | B6 | 3 | IC-103 |
| U108 | 14-Stage Binary Counter | B5 | 4 | IC-280 |
| U109 | Linear Op Amp | B2 | 5 | IC-203 |
| U110 | Current Source | A2 | 5 | IC-278 |
| U111 | Quad 2-Input NOR Gate | Several | 2 | IC-108 |
| U112 | COS/MOS Divide by "N" Counter | G2 | 3 | IC-145 |
| U113 | Quad, 2-Input, AND Gate | Several | 3 | IC-138 |
| U114 | Analog Multiplexer | D4 | 4 | IC-277 |
| Y101 | Resonator, 360kHz | E2 | 2 | CR-14 |

*Value selected during calibration at factory.

# COMPONENT LAYOUT



The PC board and LCD assembly are not secured once the case retaining screws are removed. Be careful not to allow the PC board and LCD assembly to fall out or shift out of position.

To remove the PC board from the top cover, grasp the TC switch assembly and lift the board from the cover. The two switch knobs along with the bushings, will remain in the case.

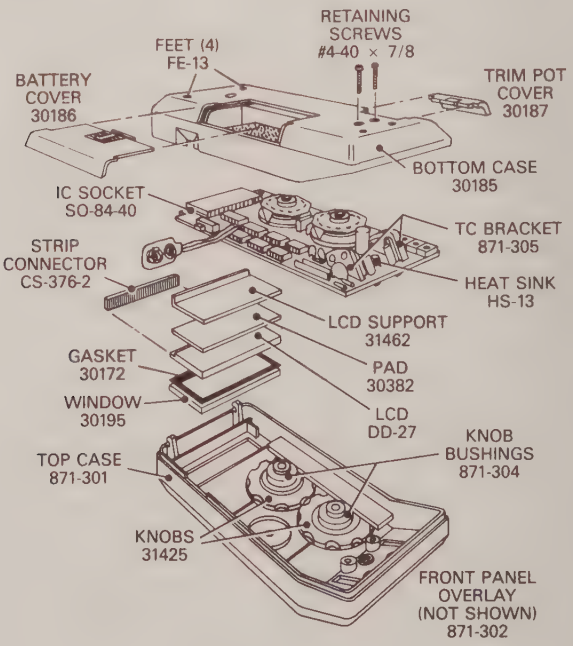
The LCD assembly will remain in the top cover when the PC board is removed. Again, be careful not to allow the LCD assembly to fall out accidentally.

The LCD assembly, along with the strip connector, lifts out of the case.

To reassemble the Model 871, reverse the above procedure.

**NOTE**

Proper alignment of the strip connector is necessary when reinstalling the LCD assembly. If the strip connector has a conductor side, make sure that side is positioned against the plastic support of the LCD assembly.



# TROUBLESHOOTING GUIDE

The following troubleshooting information is intended to be used by qualified electronic maintenance personnel who are familiar with the proper use of standard electronic test equipment.

To gain access to the PC board, refer to the first three paragraphs of the disassembly instructions. Utilize the parts list, schematic and component layout for identifying parts and check point locations. The following checks should be made with the Model 871 set to the 200°C Range.

## DC Voltage Checks

1. Battery: $V_{BAT} > 7V$
2. Power Supplies:
   V + to ⏚ (Analog Common) = +2.8 ±0.4V
   V + to ⏚ (Digital Common) = +5 ±1V
3. Reference Diode: CR101 to ⏚ = −1.23 ±0.03V
4. Negative Reference Divider: (Reference to ⏚ )

**R119**

| Pin | mV* | Pin | mV* | Pin | mV* |
|---|---|---|---|---|---|
| 2 | -210 | 5 | -204 | 8 | -195 |
| 3 | -209 | 6 | -199 | 9 | -186 |
| 4 | -204 | 7 | -198 | 10 | -173 |

*The setting of R104 and the tolerances of the resistors within the network (R119) can affect these levels by ±5%.

5. Deintegrate Comparators:
   U103, Pin 3 to ⏚ = 150 ±25mV
   U103B, Pin 6 to ⏚ = −150 ±25mV
6. Cold Junction Voltage:
   (Ambient Temperature 25° ±3°C)
   -COM to ⏚ = 1.0 ±0.6mV

## Waveform Checks: (Referenced To ⏚ )

| | | | |
|---|---|---|---|
| Clock | U111, Pin 3 | 360kHz, 5V pp | Square Wave |
| A/D Clock | U112, Pin 5 | 40kHz, 5V pp | Rectangular Wave |
| Ref. Clock 1 | U102, Pin 9 | 60kHz, 5V pp | Rectangular Wave |
| Ref. Clock 2 | U102, Pin 14 | 6kHz, 5V pp | Rectangular Wave |
| Backplane | U101, Pin 20 | 50Hz, 5V pp | Rectangular Wave |

# ACCESSORIES

**MODEL 1304 SOFT CARRYING CASE AND STAND** for the Model 871.

**MODEL 1306 DELUXE CASE** is a rugged carrying case that is large enough to accommodate the 871 plus various other articles such as a spare battery, manual, the Model 8712, etc.

**MODEL 8700 CARRYING CASE WITH BELT CLIP & HOLSTER** for the Model 8714A Probe.

**MODEL 8711A THERMOCOUPLE KIT** includes Model 8712 Thermocouple Sensor, 6m (20') of AWG #24 type K duplex TC wire, miniature TC plug/jack, standard TC plug/jack.

## Probes and Sensors

**MODEL 8712 THERMOCOUPLE SENSOR** consists of a three foot TC wire sensor that has a beaded thermocouple junction.

**MODEL 8713 IMMERSION PROBE** for liquid and general purpose applications up to 900°C.

**MODEL 8714A PENETRATION PROBE** with coiled cord for measurements of soft and semi-frozen solids.

**MODEL 8715 SURFACE PROBE** for measurement of flat surfaces of solids.

**MODEL 8716 AIR/GAS PROBE**—Exposed junction within protective shroud responds to ambient temperature while shielded from incident radiation.

**MODEL 8717 HYPODERMIC PROBE**—Miniature junction responds with one-second time constant. All stainless steel construction is suitable for food industry, biological, and chemical applications.

## SERVICE POLICY

For service on your Model 871 Digital Thermometer, contact your local Keithley representative who will be able to give you immediate assistance in most cases. Complete repair and calibration facilities are maintained in the United States, West Germany, Great Britain, France, the Netherlands, Switzerland, and Austria. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of the above locations. (Addresses are located on the back of the Service Form.)

## WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace, at our option, any instrument or part thereof which, within a year from date of shipment, proves defective upon examination. We will pay local domestic surface freight costs. (NOTE: This warranty does not cover battery replacement or damage due to battery leakage.)

**Document No. 871-901 Rev A**

KEITHLEY

# SERVICE FORM

**Model No.** _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

**Name** _____ **Phone** _____

**Company** _____

**Address** _____

**City** _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

What power line voltage is used?_____ Variation?_____

Frequency?_____ Ambient Temperature?_____°F.

Variation? _____°F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

## NOTE

If your Model 871 requires servicing, send a photo copy of this Service Form along with the instrument.

KEITHLEY

**Keithley Instruments, Inc.**/28775 Aurora Road/Cleveland, Ohio 44139/U.S.A./(216) 248-0400/Telex: 98-5469
**WEST GERMANY: Keithley Instruments GmbH**/Heiglhofstrasse 5/D-8000 München 70/(089) 714-40-65/Telex: 521 21 60
**GREAT BRITAIN: Keithley Instruments, Ltd.**/1, Boulton Road/GB-Reading, Berkshire RG2 ONL/(0734) 86 12 87/Telex: 847047
**FRANCE: Keithley Instruments SARL**/2 Bis, Rue Léon Blum/B.P. 60/91121 Palaiseau Cedex/(6) 011.51.55/Telex: 600933F
**NETHERLANDS: Keithley Instruments B.V.**/Leidsestraatweg 149/Postbus 1190 /NL-Woerden/(03480) 13 643/Telex: 40 311
**SWITZERLAND: Keithley Instruments SA**/Filiale Dübendorf/Kriesbachstr. 4/CH-8600 Dübendorf/01 821 94 44/Telex: 57 536
**AUSTRIA: Keithley Instruments Handels-Gesellschaft m.b.H.**/Döblinger Hauptstr. 32/A-1190 Wien/0222 314 289/Telex: 13 45 00